European Journal of Population
https://doi.org/10.1007/s10680-022-09610-x

An Age-Period-Cohort Approach to Analyse Late-Life Depression Prevalence in Six European Countries, 2004–2016

Octavio Nicolas Bramajo[1]

Received: 21 September 2020 / Accepted: 24 January 2022
© The Author(s), under exclusive licence to Springer Nature B.V. 2022

Abstract
Late-life depression is a condition that affects an ever-growing share of the population in ageing societies. While depression prevalence varies across countries for a myriad of reasons, generational factors, expressed in the shared experience of birth cohorts, may also play a part in such differentials. This paper describes the presence of age, period, and cohort (APC) effects in late-life depression prevalence trends (for adults aged 50 and above) for selected countries in Europe, using the Survey of Health and Ageing and Retirement of Europe (SHARE). We analysed six countries during the 2004–2016 period: Denmark, Sweden, and Germany, with a lower baseline prevalence, and Italy, Spain, and France, with a higher baseline prevalence. By applying a set of APC statistical models to visualise linear and nonlinear effects, we found that all countries followed a J-shaped curve when describing the transversal and longitudinal age trajectories of late-life depression. We also found a combination of nonlinear effects present in Germany, France and Sweden in males, indicating that younger male cohorts had a higher relative risk of depression. In females, we found nonlinear cohort effects, indicating that younger and older cohorts presented a higher risk of depression in Sweden and Germany and a lower risk in Spain. The presence of an increased risk for younger male cohorts may be indicative of a new trend in some countries, which may reduce the sex gap in prevalence. Future analysis should focus on the causes and mechanisms that lead to differential risks across cohorts.

Keywords Depression · Ageing · Cohort Studies · Descriptive Epidemiology · Social Epidemiology

A previous version of this article was presented in 2021 Meeting of the Population Association of America.

This article is part of the ongoing doctoral dissertation of the author.

✉ Octavio Nicolas Bramajo
obramajo@ced.uab.es

Extended author information available on the last page of the article

Published online: 23 February 2022

1 Introduction

Depression is currently the second leading cause of years lived with disability worldwide (Ferrari et al., 2013) and it is expected to become the primary cause of disability around 2030, according to a set of projections made by the World Health Organization (2008). Thus, it is not surprising that depression, a non-fatal disease, is gaining attention as a population health issue among researchers. In particular, late-life depression is an important public health problem due to its association with multiple negative health outcomes, including mortality (Blazer, 2005; Fiske etal., 2009; Horackova et al., 2019, Zhao et al., 2012) as well as overall poor quality of life, not only for the affected individuals but also for their partners and relatives (Pascual-Sáez et al., 2019). Understanding and analysing late-life health outcomes are becoming critically important, especially in the twenty-first century where individuals increasingly live longer lives. Addressing negative health outcomes in the later stages of life is critical for a better understanding of how social security, health care provisions, pension systems, and other aspects of social policy should perform in a society.

Depression in adults and old-age adults can manifest in a variety of feelings and mood disorders. Sometimes it is the continuation of a disease recurrent along the previous life course, but it can also be a new onset condition, or a side effect of another illness and/or medication treatments (Aziz & Steffens, 2013). Furthermore, since it is harder to notice, it is harder to measure it appropriately (Gennaro et al., 2019).

Evidence suggests that depression prevalence tends to increase in the oldest ages (Aziz & Steffens, 2013; Bell, 2014; Dewey & Prince, 2005). There is a fair share of studies focussing on cross-national differentials in late-life depression in European countries (Aichberger et al., 2010; Dewey & Prince, 2005; Hansen et al., 2017). These studies found a lower late-life depression prevalence in Northern European countries (like Denmark, Sweden, or Germany), and a higher prevalence in Southern Europe, especially in countries like Spain or Italy (Dewey & Prince, 2005; Van de Velde, Bracke, and Levecque, 2010; Aichberger et al., 2010; Horackova et al., 2019). The reasons for spatial inequalities in the prevalence of depression are not clear, but previous evidence suggests that structural socioeconomic and cultural factors may play a role (Cuadros et al., 2019; Mattheys et al., 2016).

There may be several events in the life course that trigger depression, and such outcomes may be uniquely related to the particular experiences of certain individuals (Colman and Ataullahjan, 2010). Sometimes a group of individuals that share a common characteristic (the year of birth being the most common example) is exposed singularly to a series of events during their life course, and such exposures may or may not affect them in similar ways. This notion underpins the use of cohort analysis in social research (Glenn, 2005; Ryder, 1965). Studies that address depression prevalence (or related aspects of mental health) embracing a cohort perspective are scarce, and most do not involve European countries (Keyes et al., 2014; Lavori et al., 1987; Wickramaratne et al., 1989). Bell (2014)

analysed mental well-being across a group of cohorts in the United Kingdom, finding curved mental health age trajectories in late life, with a steep increase in the last years of life, and a relative deterioration of the mental well-being of the younger cohorts when compared to the older ones. Moreover, he found that gender and marital status were strongly related to mental health, with females and non-married individuals presenting the worst outcomes. Spiers et al. (2011) conducted study with similar goals in England, but did not find differences in the prevalence of mental disorders across English cohorts.

Furthermore, there is evidence suggesting that periods of abrupt financial difficulties and other stresses may cause spikes in negative mental health outcomes of the affected populations (Frasquilho et al., 2016; Riumallo-Herl et al., 2014; Thomson et al., 2018). This is not surprising, considering that inequalities in health are socially based (Marmot, 2005) and mental health is no exception (Fryers et al., 2003). It should be noted that not all inequalities in mental health are the result of a specific event, but rather are strongly associated with structural factors. Socioeconomic status, living standards, social interactions, marriage status, and other dynamic aspects influence mental health outcomes (Bell, 2014; Fryers et al., 2003). Furthermore, not all individuals of a given group are evenly likely to be affected by a particular event: mental health and late-life depression is an exemplary case of a phenomenon that affects more females than males, for instance (Aziz & Steffens, 2013; Blazer, 2005).

Analysing trends over different periods in late-life depression, and differentials across countries by age and sex (as well as the specific factors underlying such differences) is critical to understand better this particular condition. Researchers disentangle such trends over time into three types of effects: age effects, period effects, and cohort effects. Age is arguably the most well-known of the three, and it refers to effects that are the consequence of the unavoidable ageing process of individuals in a certain population. Period effects are defined as the secular trends on a given phenomenon that occur across all age groups in a particular moment (Keyes et al., 2014). The third dimension, cohort effects, corresponds to changes across groups of individuals who share a certain characteristic (usually, individuals that come from the same birth cohort) which experience certain events or exposures across their life course together from a chronological point of view (Hobcraft et al., 1982; Ryder, 1965; Yang & Land, 2013).

Approaches that try to decompose age, period, and cohort effects separately are known as Age-Period-Cohort (APC) models (Acosta & Van Raalte, 2019; Holford, 1992; Keyes et al., 2014; Yang & Land, 2013). These models constitute a descriptive tool that is particularly useful to analyse trends over time of certain phenomena, that may (or may not) present changes across certain birth cohorts.

2 Research Objective

This study intended to disentangle age, period, and cohort effects in late-life depression prevalence in selected European countries, separately by sex.

3 Data and Method

3.1 Data Source and Definitions

The main data source used for this study was the Survey of Health, Ageing and Retirement in Europe (SHARE). SHARE is a multiple-wave panel study that follows cohorts of non-institutionalised respondents aged 50 and over in several European countries from 2004 onwards. Successive waves were collected in 2007, 2011, 2013, 2015, and 2017 (and one special retrospective survey, also known as SHARELIFE, in 2009). The first wave started collecting data from twelve countries: Germany, the Netherlands, Switzerland, Austria, Sweden, Denmark, Spain, France, Italy, Belgium, Greece, and Israel. During the following waves, more countries were added to the survey, more than doubling the initial group. Each wave is considered to be representative of the population of the surveyed countries (Börsch-Supan, 2019; Bergmann et al., 2019). The survey provides information about the physical and mental health of the respondents (both at a household and individual level), among other detailed aspects of their sociodemographic characteristics (educational attainment, wealth, social support among others) and overall well-being.

3.2 Dependent Variable

Late-life depression prevalence is the main dependent variable of this study. SHARE utilises the 12-item EURO-D scale, which has been validated in other studies (Prince et al. 1999; Guerra et al., 2015). We followed the criterion established by Dewey and Prince (2005) to define clinically significant depression, also discussed and validated within the aforementioned previous studies (Prince et al. 1999; Guerra et al., 2015). According to this criterion, a EURO-D score of 4 or higher (from a scale of 12 non-weighted items, with every item presenting a value of 1, which results in a score ranging from 0 to 12), means that the respondent "would be likely to be diagnosed as suffering from a depressive disorder, for which therapeutic intervention would be indicated" (p. 109). Therefore, we defined late-life depression based on individuals aged 50 years and above that reported scores equal or higher than the defined threshold value. We considered only cases that offered a response to the depression scale in the survey as valid.

3.3 Country Selection And Treatment Of The Data

The small sample size forced us to make some assumptions and decisions regarding the composition of the population in terms of ages and cohorts (and the countries deemed as suitable for the analysis). Seven SHARE waves were collected during the 2004–2017 period. However, the SHARELIFE survey, corresponding to Wave 3 in 2009, did not involve reports on depression prevalence.

Considering the a priori unequal period timespans of the collected waves, we found a four-age group distribution suitable for this study. The range of those nine

four-age groups varies from ages 50 to 53 (age 52 being the mean year for that group) to age 82 and over as the last open-ended group. To make intervals better suited for APC analysis, we opted to merge waves 4 and 5 to the midpoint (2012), and also did the same for waves 6 and 7 (midpoint of 2016). Therefore, we considered the results for the midpoint as the average of the results of the merged periods, which we believe is a reasonable assumption. We also made another strong assumption, namely that the prevalence for the year 2007 (corresponding to Wave 2) was similar to that for 2008. This made it possible to present four observations with similar intervals: 2004, 2008, 2012, 2016 (removing the corresponding cases that were present in both waves to avoid duplication of effects), allowing us to recreate "pseudo"-cohorts with that particular allocation of waves. Given that depression is a phenomenon that is persistent in some cohorts (Bell, 2014), and that variations in prevalence from 1 year to another are modest, we believe that these assumptions are reasonable, and should not affect the results in any major way.

As a result, the selected cohorts encompass those who were born between 1920 and 1964. A small set of countries participated in all of the SHARE survey waves and reported questions about depression prevalence, limiting the potential for follow-up studies. Three of those countries presented a lower depression prevalence by age in the first wave (Denmark, Sweden, and Germany), and the remaining three presented higher depression prevalence in that very same wave (Italy, Spain, and France). Figure 1 presents the age-specific rates for the baseline period (2004) for

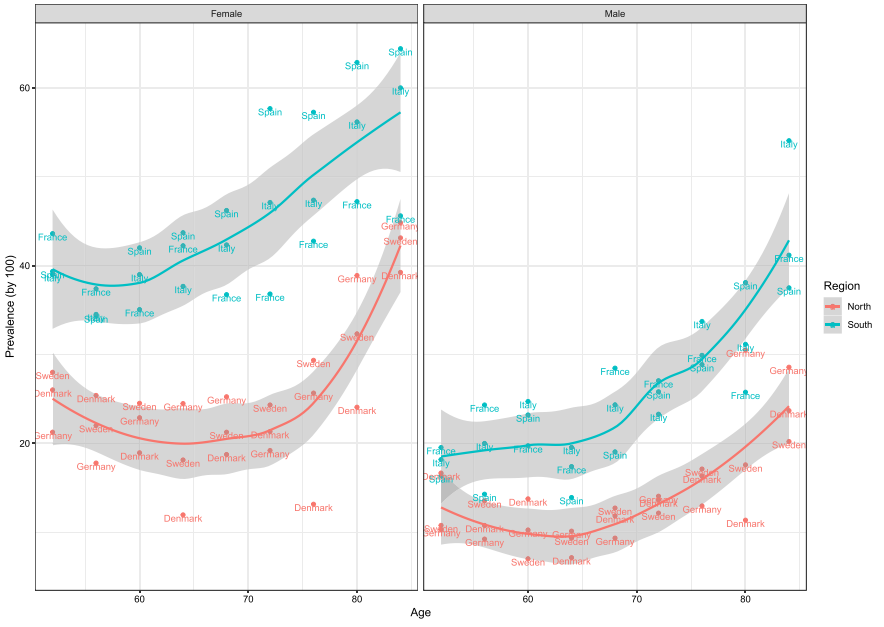

Fig. 1 Age-Specific Prevalence of Depression by Country and Region in 2004. (Author's calculations based on SHARE-ERIC)

countries belonging to each group, expressed in "North" and "South" regions, with the former showing a lower age-specific prevalence.

Given that we did not know beforehand if trends differed within countries of the same region, we modelled effects at an individual country-level instead of adapting a hierarchical modelling approach. Therefore, we analysed 432 age-period interactions (nine age groups, two macro-regions and four periods, separately by the two sexes). The total sample size for all countries and periods was 125,791 persons: 56,999 males and 68,792 females: more details can be found in Table 2 in the appendix. The resulting age-period-cohort tabulation is also present in the Appendix in the Table 3.

3.4 Analytical APC Strategy

First, we performed an exploratory analysis, involving a series of techniques (age-standardised rates, two-dimensional plots, analysis of deviance) to determine if the APC modelling strategy was helpful for our research purposes. For practical reasons, we presented in the main text only the age-standardised prevalence by country (using the overall sum of the exposure considering both males and females of the six countries, by four-age groups, in the 2004 wave as the reference population. This reference population is also shown in the appendix in Table 4); the contribution of the linear and nonlinear effects to deviance reduction (when compared to an age model); and the point estimates for the drift (the maximum likelihood estimates of the drift) and the age-drift model. The two-dimensional age-by-period, period-by-age, age-by-cohort and cohort-by-age plots can be found in the appendix (Figs. 8, 8, 10, 11). Each of these figures was produced with the *ggplot2* package developed for R software (Wickham, 2016).

APC models have some inherent limitations, the most important being the linear identification problem. This refers to the impossibility of separating the Age, Period, and Cohort effects from a mathematical point of view (Acosta & van Raalte, 2019; Bell, 2014; Carstensen, 2007; Holford, 1992; Nielsen & Nielsen, 2014; Yang & Land, 2013), since the three dimensions are perfectly collinear. As we already know: Age is the equivalent of Period minus Cohort, Period equals Age plus Cohort, and Cohort equals Period minus Age. As a result, any linear model that presents the three dimensions as explanatory variables would offer an infinite number of possible solutions. A series of possible approaches to deal with (but not solve) the linear identification problem has been developed. An overview of some of the most commonly used methods is provided in Yang and Land (2013) and Fosse and Winship (2019), and further comments about alternative graphical methods can be found in Acosta and van Raalte (2019).

One well-known alternative involves constraining one of the period/cohort dimensions (Carstensen, 2007; Clayton & Schifflers, 1987; Holford, 1992), and assigning the linear trend (also known as drift) to the other one to produce a unique set of estimable functions for the three effects. The constrained dimension would have a zero slope and a zero average as well, being stripped of its linear trend. This "detrended" dimension would be expressed in the form of

rate-ratio residuals, as an interaction of the remaining two dimensions (Chauvel & Schröder, 2014). Such a result would indicate the presence of nonlinear, second-order effects that are identifiable, independently of the chosen parameterisation (let it be cohort-based or period-based), referred to as the average trend of the chosen dimension. The dimension that carries the drift would be represented in terms of the relative risk to a reference value (and an arbitrarily chosen cohort/period), and the remaining dimension would be expressed in terms of log-rates (most likely the age dimension, because it tends to be the strongest dimension for explaining variation of a given phenomenon).

In other words, in this approach, the APC effects are treated as nonlinear estimable functions of *(a)*, *h(c)*, and *g(p)* respectively, along with the aforementioned linear drift, which is flexible based on the chosen parameterisation. However, it must be noted that two different parameterisations will not produce two identical models (Carstensen, 2007; Clayton & Schifflers, 1987). If a cohort-based parameterisation is chosen, log-rates for the age dimension will be expressed in terms of the reference cohort in the model (also known as longitudinal age effects). If a period-based parameterisation is chosen, log-rates for the age dimension will be expressed based on the reference period (transversal age effects). Therefore, while probably similar, age effects differ slightly with this strategy. The linear drift and nonlinear cohort and period effects remain unchanged with this approach.

Both parameterisations (period-based and cohort-based, respectively) could be expressed as:

1. $\ln(d(a,p)) = r_{\mathrm{pe}}(a) + \delta\left(p - p_0\right) + g(p) + h(c)$
2. $\ln(d(a,\mathrm{c})) = r_{\mathrm{co}}(a) + \delta\left(\mathrm{c} - \mathrm{c}_0\right) + g(p) + h(c)$

where $r_{\mathrm{pe}}(a)$ are the age-specific prevalence rates in the reference period $r_0$and $r_{\mathrm{co}}(a)$ are the age-specific prevalence rates in the reference cohort c_0; δ represents the linear drift; *h(c)* is the cohort function, and *g(p)* is the remaining period function. In the first equation, the sum of period effects is interpretable as the log relative risk to the period of reference p_0, and in the second equation, the sum of cohort effects is interpretable as the log relative risk to the cohort of reference c_0.

When analysing mental health trends, some authors argue that we can make strong assumptions about which dimension gets the linear trend with the proper theoretical foundation (Bell, 2014; Spiers et al., 2011). Those assumptions suggest that it is unlikely that we can expect a continuous linear period trend affecting all age groups, apart from some specific valleys or peaks in certain contexts (like the last European recession, for instance). As a result, changes in prevalence of mental disorders over time are more likely to be explained by cohort effects, manifested in the lingering experiences of individuals during their life course (Bell, 2014). However, since it is not possible mathematically to confirm such assumption, we cannot assume that period linear trends should be non-existent in this case. Therefore, we decided to take advantage of this flexibility and present two different parameterisations to interpret the results, noting that other researchers have relied on the same strategy previously (Dobson et al., 2020).

The "*Epi*" package was developed in R software (Carstensen et al., 2019) to analyse APC trends (among many other possible uses) and we used it to visualise the effects of each separate dimension of Age, Cohort, and Period for the selected regions. Furthermore, as mentioned by Acosta and van Raalte (2019), the Detrended-APC model allows the researcher to compare effects across different populations easily, and also works well with relatively sparse data (Dobson et al., 2020).

While we discussed briefly the general aspects of APC modelling, other technical details are worth mentioning about this particular study. The *apc.fit* command of the Epi package allows the user to choose a series of options for fitting the data. We opted for the natural cubic splines fitting, which offers an easier visualisation of rates when compared to three-factor linear models (Carstensen, 2007). We have chosen the naïve weights for the inner product in matrix multiplication for extracting the drift, and three knots in the period dimension instead of the standard five knots used for the other dimensions for fitting the cubic splines (because the standard value would probably result in overfitting, given the scarcity of data in that particular dimension). Finally, given that in this approach the three dimensions are considered as continuous variables, we chose the 2004 period (for the period-based or APC model, following notation present in the Epi package) and 1944 cohort (for the cohort-based or ACP model) as the reference points for the models.

As a side note, while the chosen strategy does not "solve" the linear dependency problem (and neither does it claim to), we acknowledge that bias that may result from the chosen parameterisation is a consequence of the assumptions made by the researchers.

4 Results

4.1 Age-Standardized Prevalence

Figure 6 shows the Age-Standardised Prevalence of depression prevalence in the selected countries by sex, for the population aged 50 and above during the 2004–2016 period. As expected, age-standardised Prevalence was higher for females than males, and higher for the countries in the South group when compared with the North group. While Denmark, Sweden, and France showed very modest changes in the age-standardised prevalence, Germany presented an increase in prevalence for both sexes. The prevalence in Spain declined across the analysed period, notably more for females than for males, where the improvement was more modest. Italy also presented an improvement over the 2004–16 period, but this was more modest in comparison to Spain.

Additional results presented in the appendix (figures from 8, 9, 10, 11, indicating a series of two-dimensional, exploratory plots between age-period and cohort interactions) were suggestive of the presence of some parallel lines (which could indicate the existence of linear effects, particularly in the South group). However, some were overlapping as well, which could indicate a variety of nonlinear effects, specifically for younger cohorts.

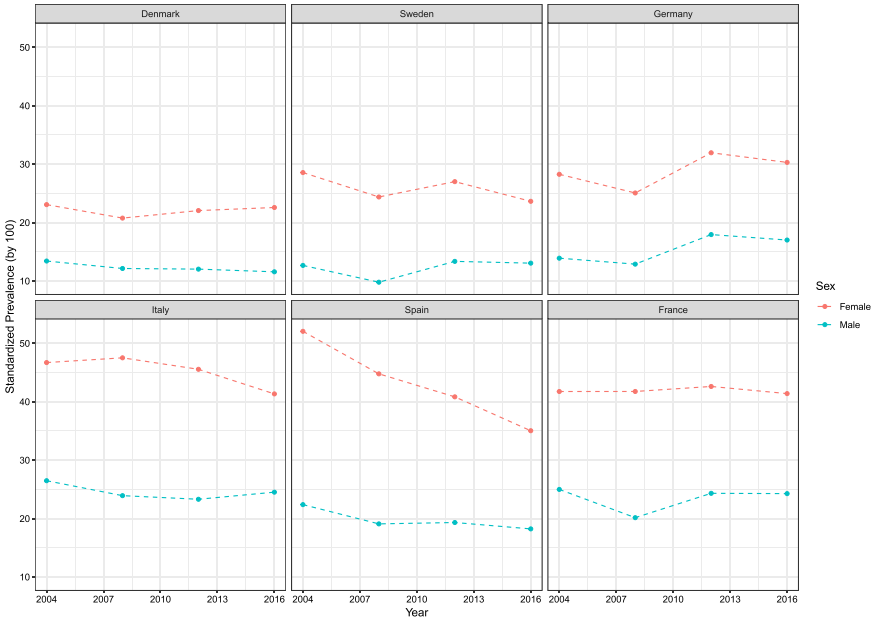

Fig. 2 Age-standardised depression prevalence by country (author's calculations based on SHARE-ERIC)

4.2 Contribution To Deviance Reduction In Models

Figure 3 shows the average contribution to the deviance reduction between a one factor age model and the remaining models, separating between drift (the linear component that can be attributed to cohort or period) and nonlinear effects of period (AP model) and cohort (corresponding to full APC models in this case). Additional information, such as the model deviance and the *p*-value results can be found in Table 4 in the Appendix. It should be noted that both the value of the contribution and the *p*-value (likelihood ratio test) depend on the degrees of freedom in the models, and while it is useful to identify the average deviance, it tells us more about the chosen tabulation rather than the model adequacy (Carstensen, 2007). To complement this figure, we also presented the point estimates to the drift and, the age-drift model, as shown in Table 1.

In those countries with slight to no variation in age-standardised depression prevalence over time. the contribution of drift to the reduction of deviance was relatively small. as expected. Germany and Spain, however, do present linear trends worth noting, as expressed both in the relative contribution of the drift in Fig. 7 and in the ML-estimates. For Germany, the long-term trend indicates an increase in prevalence (expressed in the ratio above 1), and in Spain a strong improvement (lower prevalence). While it is possible to argue that for females in Italy there might be a small drift indicating long-term improvement, the confidence intervals of the estimate do not support this conclusion. While the contribution of nonlinear cohort effects was

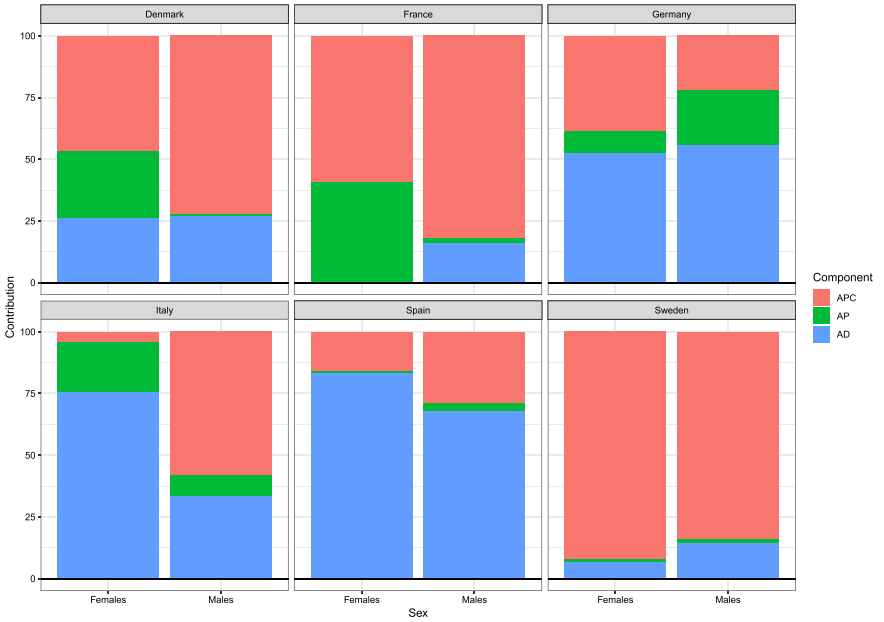

Fig. 3 Contribution to deviance reduction between Age and APC models in selected countries. (author's calculations based on SHARE-ERIC)

Table 1 ML Estimates of Drift and Age-Drift models in selected countries (author´s calculations based on SHARE-ERIC)

Country	Sex	Females			Males		
	Component	Estimate	2.5%	97.50%	Estimate	2.5%	97.50%
Denmark	Drift	1.006	0.993	1.019	0.992	0.974	1.011
	AD	1.006	0.994	1.018	0.992	0.975	1.008
Sweden	Drift	0.999	0.989	1.010	1.002	0.986	1.019
	AD	0.997	0.987	1.006	1.011	0.996	1.026
Germany	Drift	1.019	1.009	1.028	1.037	1.022	1.051
	AD	1.021	1.012	1.030	1.031	1.018	1.045
Italy	Drift	0.993	0.986	1.000	0.994	0.983	1.004
	AD	0.993	0.986	1.000	0.992	0.982	1.002
Spain	Drift	0.971	0.963	0.978	0.975	0.962	0.988
	AD	0.974	0.967	0.980	0.977	0.965	0.988
France	Drift	1.000	0.992	1.008	1.002	0.991	1.014
	AD	1.000	0.993	1.007	1.009	0.998	1.019

larger than the period in all cases (which could be attributed to the fact that there are more cohorts than periods in the analyses), this does not indicate per se the presence of cohort effects that are visible in an APC model (partly because contributions are

expressed in relative terms, and partly because of the arguably high values in the likelihood ratio tests).

4.3 Visualisation Of Age, Period, And Cohort Effects

Figures 8 and 5 describe the effects of the APC (period-based) and ACP (cohort-based) models in the selected countries for males, respectively. Age effects in both scenarios presented a J-shaped pattern, with a steep increase in prevalence nearing age 70 (and in some cases, a slight drop in prevalence right before that age, with the degree of concavity varying by country). The sole exception is Germany, where the age effects for the cohort-major model were much steeper than for the period model, where they remained more or less stable. Two countries did not seem to present any deviation from the average trend in terms of period and cohort effects: Denmark and Italy. In Sweden and France, we identified some nonlinear cohort effects indicatint that the younger cohorts and some of the older cohorts presented a relative risk above the average trend. In the alternative parameterisation (incorporating the linear drift in the cohort dimension), we can observe that the younger cohorts present a higher relative risk when compared to the reference cohort. We also found nonlinear cohort effects in Germany, indicating a higher relative risk for the younger and older cohorts, and that the period dimension (which incorporates the linear trend in this case) presented a steep increase in relative risk when compare to the reference

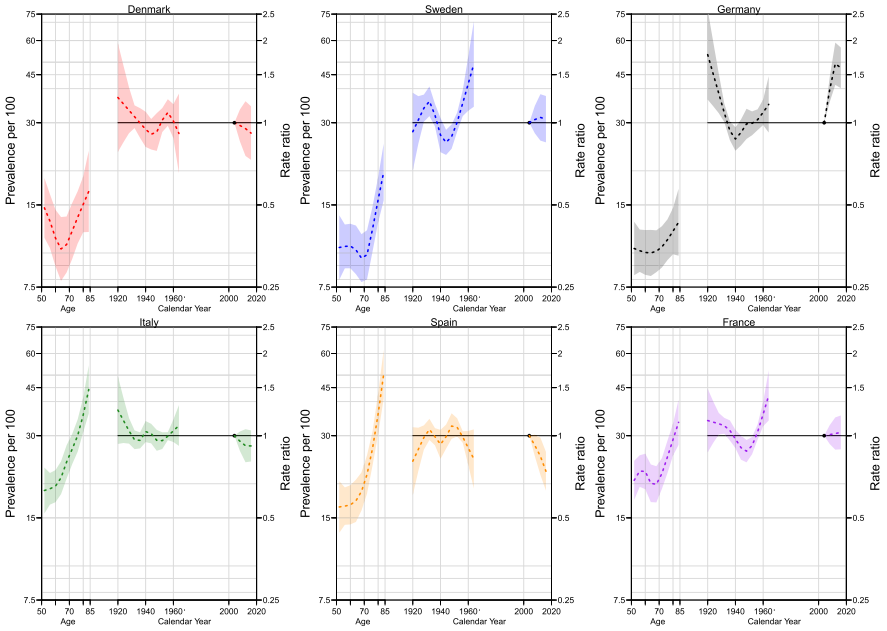

Fig. 4 Age, Period and Cohort effects of Depression Prevalence in selected countries, Males -APC Model (author's calculations based on SHARE-ERIC)

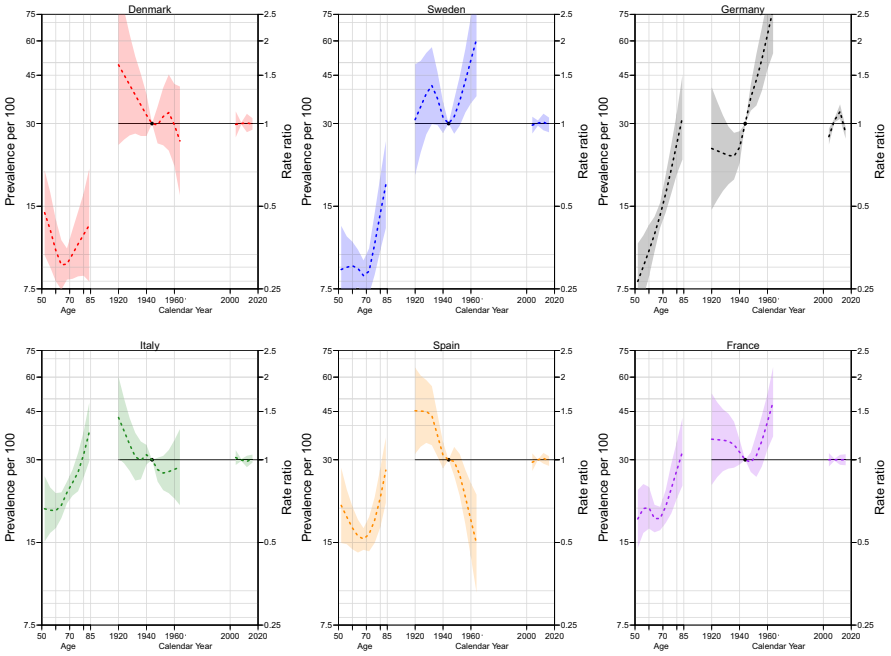

Fig. 5 Age, Period and Cohort effects of Depression Prevalence in selected countries, Males -ACP Model (author's calculations based on SHARE-ERIC)

period (Fig. 4). In the cohort-major parameterisation, subsequent younger cohorts presented a much higher risk than the reference point (but the older cohorts did not present a higher risk when compared to the 1944 reference cohort). We also detected nonlinear period effects, with the highest risk found in the 2012 period. For Spain, another country with a strong drift, we failed to identify clear nonlinear effects in both parameterisations (in the case of nonlinear cohort effects, this was partly due to the wide confidence intervals), while the dimension that had the linear trend incorporated presented a strong improvement in each parameterisation.

Figures 6 and 7 describe the Age, Period, and Cohort effects for females. Just like the previous case, age trajectories show a similar = shape for both parameterisations, but with a higher intensity when compared to males.

Denmark, Italy, and France did not present any identifiable significant effects. In the case of Sweden, there were some nonlinear cohort effects present in the older and particularly in the younger cohorts that suggest a higher relative risk when compared to the cohorts born near 1940 (with the lowest relative risk). In the alternative ACP parameterisation, we did not obtain any clear difference in risk when compared to the reference cohort (1944). In Germany, in the APC model we found that cohorts born between 1944 and 1952 presented a relative risk lower than the average trend, and cohorts born near 1930 and 1960 had a relative risk above the trend, while in the period dimension there was a sustained increase in prevalence over time. The alternative ACP parameterisation, indicates that most cohorts born after 1944 had a relative risk higher than the chosen reference, while this was not entirely clear for

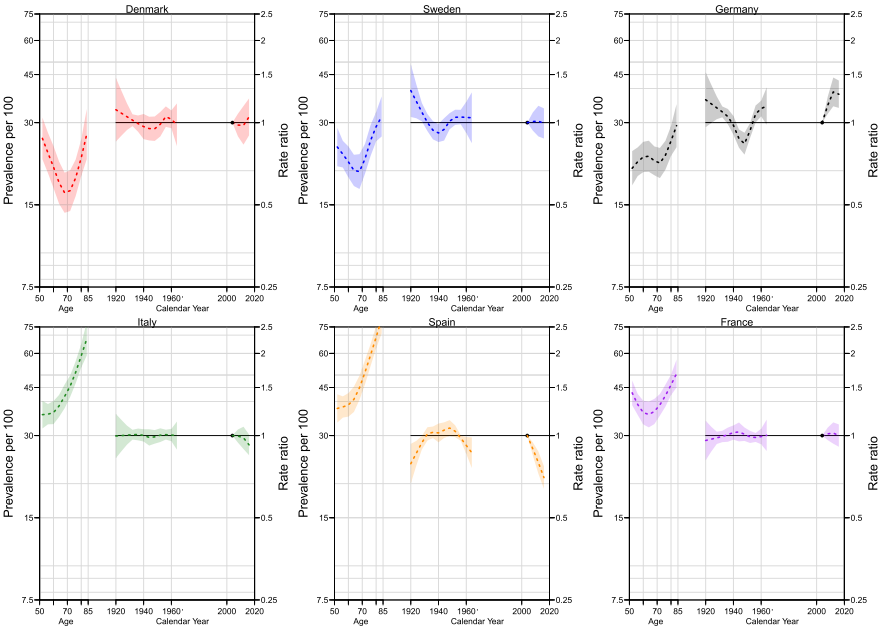

Fig. 6 Age, Period and Cohort effects of Depression Prevalence in selected countries, Females -APC Model (author's calculations based on SHARE-ERIC)

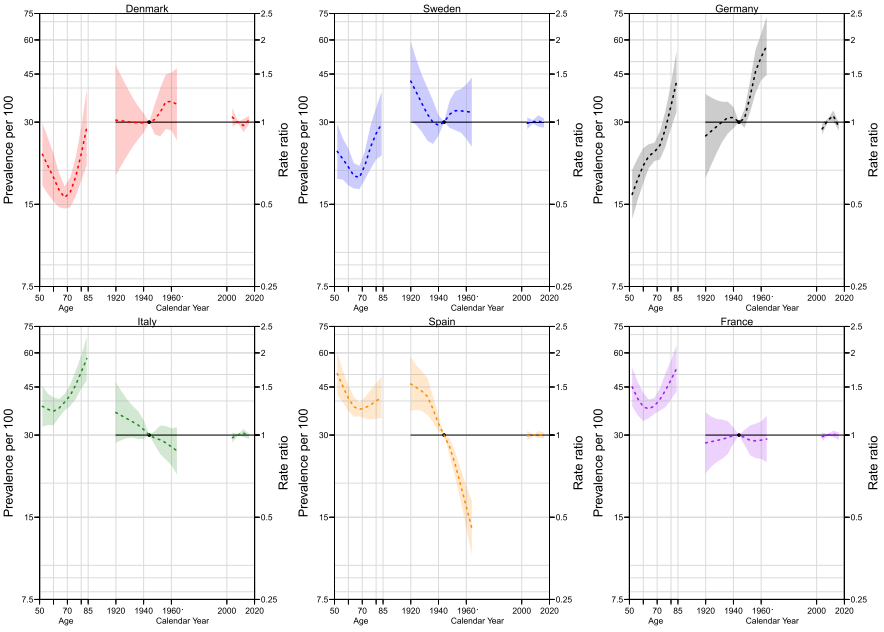

Fig. 7 Age, Period and Cohort effects of Depression Prevalence in selected countries, Females -ACP Model (author's calculations based on SHARE-ERIC)

those born before. Unlike for males, nonlinear period effects were not as evident in this case. For Spain, nonlinear cohort effects could be identified in the oldest and youngest cohorts, which showed values below the average trend, along with a strong improvement in the period dimension, when compared to 2004. In the alternative parameterisation, nonlinear period effects were absent and the cohort dimension that had the drift indicated a strong decline in the relative risk for those born after 1944, and a higher relative risk for those cohorts born before.

5 Discussion

5.1 Conclusions

Our findings suggest that in some cases the prevalence of depression remained stable over time (indicating an absence of any period or cohort effects), while in others, we found a combination of linear and nonlinear effects that could represent the beginning of new trends.

Age effects appeared to be similar across countries and by sex, with a curve pattern, with small differences observed for transversal and longitudinal trajectories in general, and an important increase in depression prevalence after age 70. The decrease in depression prevalence between ages 60 and 70 may be consistent with previous literature that indicates that retirement is beneficial for mental health (Fernández-Niño et al., 2018; Oksanen et al., 2011), and the increase at older ages may be related to the ageing process of the body and its consequent deterioration, as well as to greater social isolation experienced at older compared to younger ages. However, the models do not tell us anything about the transition to the retirement of the analysed population or their later life activities, so any indications that retirement could be the cause of any concavities are purely speculative.

In regards to the period and cohort dimensions, the presence of effects was somewhat more noticeable in males than females: we found linear and/or nonlinear effects in four of the six chosen countries. In Germany, Sweden and France, we identified nonlinear cohort effects, manifested in an increase of the relative risk of depression in the younger birth cohorts. Germany is arguably the more complex case: apart from those nonlinear cohort effects, it also presented nonlinear period effects and a strong linear trend indicating an increase of the relative risk over time. Spain, on the contrary, presented a strong drift that indicated a sustained improvement but we were unable to find any nonlinear effects in males. Although the true extent of the effects may not be fully identifiable, we found that cohorts may be partly responsible for the ongoing trend in the first three countries. In the case of females, while overall prevalence was higher than for males (for all age groups), only in three countries did we find effects worth commenting on: Sweden and Germany, that presented a variety of nonlinear cohort effects affecting mostly the younger and older cohorts (only the former for Sweden), and Spain, where the opposite occurred. Just it was the case for males, both Germany and Spain also presented a strong linear trend in the same

directions as before. However, the case of Spanish females is a reminder that while nonlinear cohort effects are fully identifiable and have a unique solution, the complete interpretation of relative risks across cohorts may demand further analysis: the older cohorts have a lower relative risk when compared to the 1944 cohort when considering a period-major parameterisation, but, if we put the strong linear trend in the cohort dimension, the model indicates that those older cohorts have a higher relative risk than the 1944 cohort, which is the reference for that model. Therefore, while is not clear what happens with the older Spanish cohorts in terms of relative risk, the younger cohorts present a simpler interpretation: in both parameterisations the younger cohorts have a relative risk below the cohort that was used as a reference in the ACP model. The opposite stands for Germany: here there is a clear increase in relative risk in younger female cohorts (when compared to the 1944 cohort). Therefore, we can affirm that, for females, some of the improvement in Spain and the increased risk in Germany is driven (at least partly) by cohort factors.

While it is possible to predict future rates with an APC framework (Carstensen, 2007) and the Epi package offers such possibility, given that the period trend is relatively short and the confidence intervals are wide, we decided to not present a potentially unreliable estimate. However, since younger birth cohorts present a relative risk above the average cohort trend in some countries, it would be reasonable to expect an increase in prevalence in the future if such effects persist, particularly for males, as it was the case for three countries. As a result, the sex gap in prevalence may be smaller in such cases.

5.2 Possible Limitations

This study has some shortcomings. First, "mental health" is a dynamic concept (Bell, 2014). While Depression could be chronic and a permanent feature in the life of an individual, sometimes it may be only temporary as well. Moreover, the EURO-D scale, despite being validated, has the same limitations as most other scales: they have to rely on the honesty and the accuracy of the respondent's reporting. Moreover, the interpretation and reporting of depression may differ country due to cultural differences. However, given that other scales have been used before with similar findings, is unlikely that differences could be attributed to cultural interpretations of the question. In addition, the decision to merge survey waves to produce APC models may result in a degree of bias because of this arbitrary decision.

There is also the question of coverage: while some authors have observed an East–West gap in late-life depression prevalence (Hansen et al., 2017) since no eastern European countries took part in all of the waves of SHARE, we could only focus on the South and North regions for this analysis. Most importantly, while it is clear that prevalence trends are different across countries, the reasons why those trends and variations occur are still unclear, and the relative risks shown in the models may not persist across the same cohorts over time (Acosta & van Raalte, 2019; Chauvel et al., 2016).

5.3 Final Comments

Despite such limitations, this study tried to visualise trends in the late-life prevalence of depression across some countries in Europe, by modelling age, period, and cohort effects (with a set of models with flexible parameterisations) and found that younger male cohorts in three of the six analysed countries and younger female cohorts in two of those countries presented a higher relative risk than the average trend (and in one case younger female cohorts presented a lower relative risk), confirming that late-life depression has, in some cases, a generational component. Hence, it is expected that future studies in regards to late-life depression would consider the differential experiences lived by birth cohorts as a factor of inequalities in health. However, the role of space (as a summary of existing and previous social, political and economic conditions and processes) is not clear in regards to depression. Although in the baseline age-specific prevalence we could find two possible patterns of depression intensity, countries presented diverging trends and effects over time, independently of the region. The strong, opposite trends presented for Spain and Germany are also worth monitoring in further analyses, focussing on the reasons for such a divergence, that may be related to social structures in each country. The same can also be said for the increased risks in the younger Swedish and French birth cohorts. Finally, in light of the COVID-19 pandemic, there is the possibility that future late-life depression trends may shift dramatically. This is worthy of future monitoring.

Appendix

See Figures 8, 9, 10 and 11 and Tables 2, 3, 4 and 5.

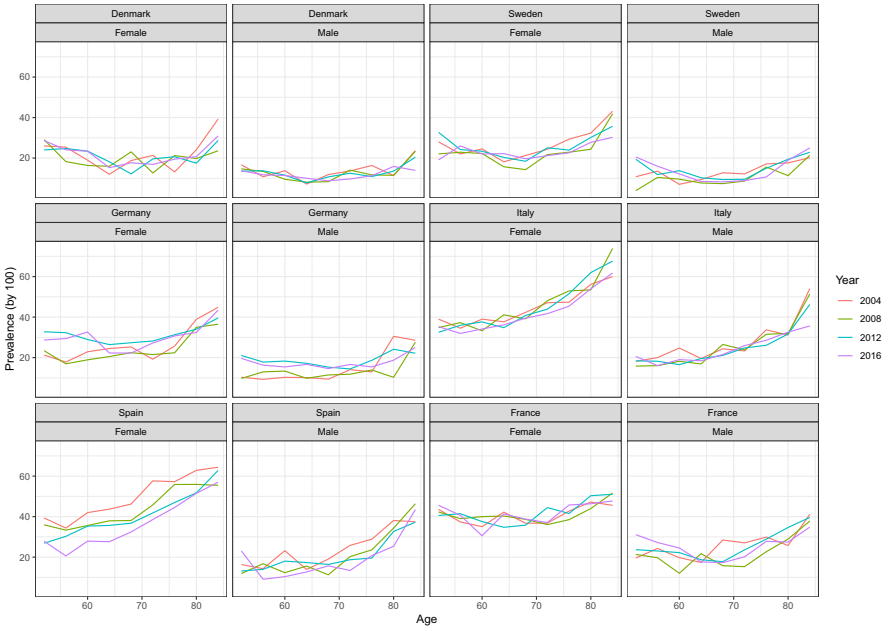

Fig. 8 Period-by-age depression Prevalence in selected countries, by sex (author's calculations based on SHARE-ERIC)

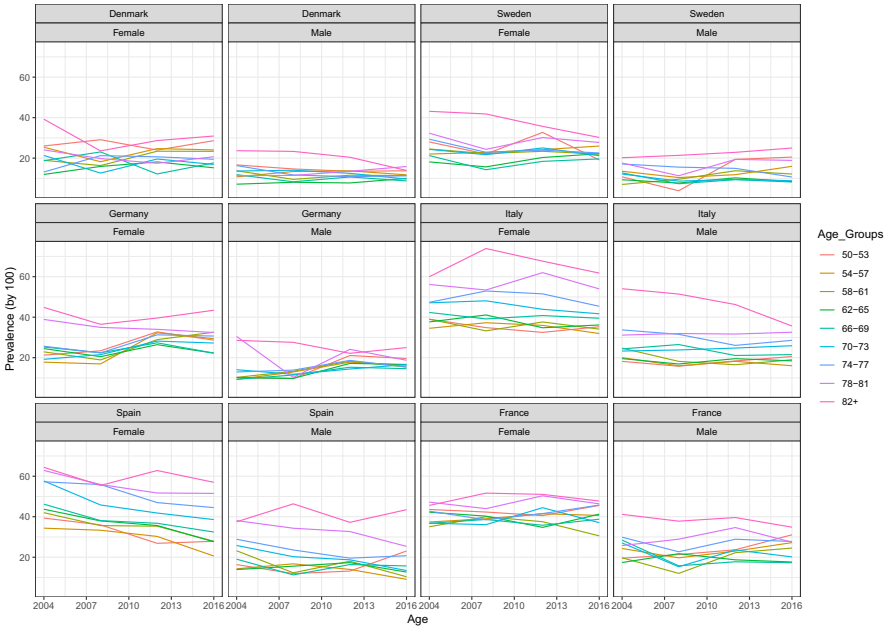

Fig. 9 Age-by-period depression prevalence in selected regions, separate by sex. (author's calculations based on SHARE-ERIC)

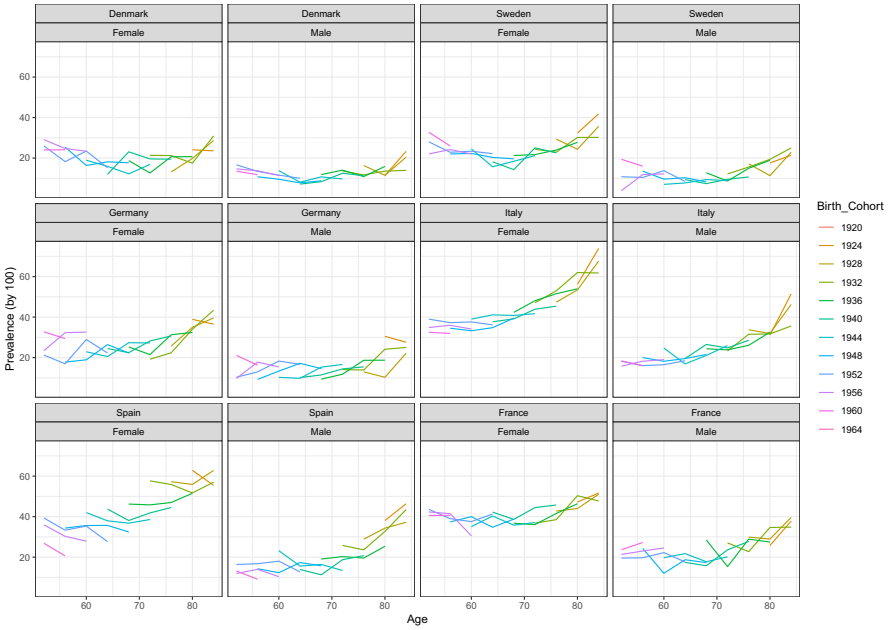

Fig. 10 Cohort-by-age depression Prevalence in selected regions, separate by sex. (author's calculations based on SHARE-ERIC)

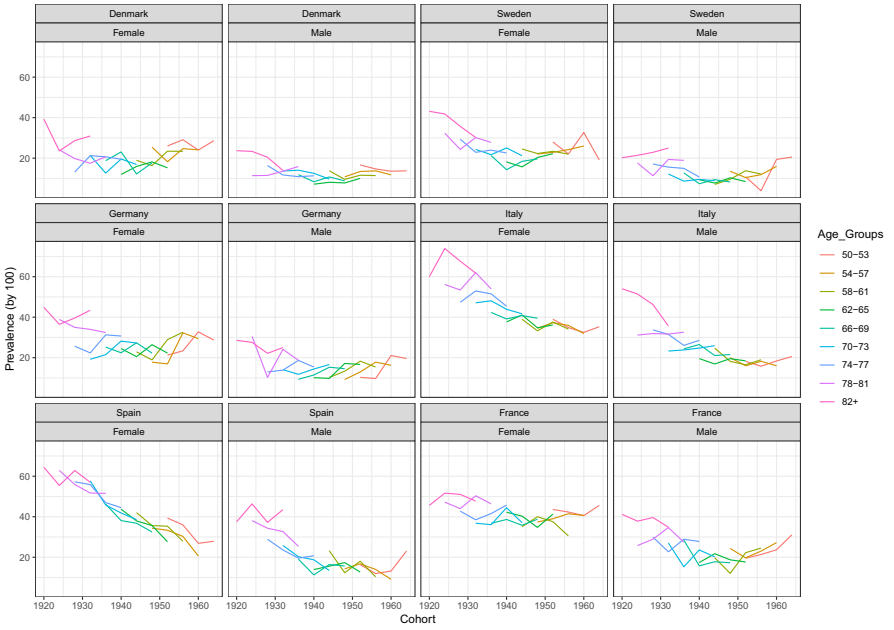

Fig. 11 Age-by-cohort depression Prevalence in selected regions, separate by sex. (author's calculations based on SHARE-ERIC)

Table 2 Reported cases by sex and country during the 2004–16 period (author's calculations based on SHARE-ERIC)

Country	Period	Males	Females
Denmark	2004	728	837
	2008	1143	1338
	2012	2856	3295
	2016	3104	3570
Sweden	2004	1378	1551
	2008	1973	2276
	2012	2944	3398
	2016	2458	3062
Germany	2004	1344	1521
	2008	1884	2161
	2012	3378	3699
	2016	3070	3609
Italy	2004	1108	1355
	2008	2120	2476
	2012	3611	4326
	2016	3614	4598
Spain	2004	929	1260
	2008	1634	1977
	2012	4440	5210
	2016	3334	4269
France	2004	1227	1541
	2008	1882	2428
	2012	4197	5511
	2016	2643	3524
Total	2004–2016	56,999	68,792

Table 3 Age-Period-Cohort tabulation in middle points

	MidYear	2004	2008	2012	2016
Age groups	Midpoint	Birth Cohort (Mid Point)			
50–53	52	1952	1956	1960	1964
54–57	56	1948	1952	1956	1960
58–61	60	1944	1948	1952	1956
62–65	64	1940	1944	1948	1952
66–69	68	1936	1940	1944	1948
70–73	72	1932	1936	1940	1944
74–77	76	1928	1932	1936	1940
78–81	80	1924	1928	1932	1936
82 +	84	1920	1924	1928	1932

Table 4 Population of reference and weights (author's calculations based on SHARE-ERIC)

Age groups	MidYear	Exposure	Weight
50–53	52	2086	0.1411462
54–57	56	2232	0.1510251
58–61	60	2139	0.1447324
62–65	64	1981	0.1340416
66–69	68	1781	0.1205088
70–73	72	1520	0.1028486
74–77	76	1196	0.0809256
78–81	80	930	0.0629271
82 +	84	914	0.0618445

Table 5 Model deviance and contribution to the deviance reductions of linear and nonlinear effects in selected countries (author's calculations based on SHARE-ERIC)

Country	Sex	Females			Males		
	Component	Model deviance	Contribution compared to age (%)	*P*-Value	Model deviance	Contribution compared to age (%)	*P*-Value
Denmark	Age	37.19	0.00	NA	16.03	0.00	NA
	AD	36.22	26.22	> 0.10	15.05	27.30	> 0.10
	AP	35.22	27.03	> 0.10	15.03	0.56	> 0.10
	APC	33.49	46.76	> 0.10	12.44	72.14	> 0.10
Sweden	Age	32.64	0.00	NA	45.33	0.00	NA
	AD	32.16	6.85	> 0.10	43.38	14.41	> 0.10
	AP	32.08	1.14	< 0.10	43.19	1.40	< 0.01
	APC	25.63	92.01	< 0.10	31.8	84.18	< 0.01
Germany	Age	76.58	0.00	NA	66.47	0.00	NA
	AD	55.53	52.39	< 0.01	43.69	56.03	< 0.01
	AP	51.95	8.91	< 0.01	34.75	21.99	< 0.05
	APC	36.4	38.70	< 0.01	25.81	21.99	< 0.05
Italy	Age	17.81	0.00	NA	23.4	0.00	NA
	AD	13.49	75.66	< 0.05	20.92	33.51	> 0.10
	AP	12.35	19.96	> 0.10	20.3	8.38	> 0.10
	APC	12.1	4.38	> 0.10	16	58.11	> 0.10
Spain	Age	84.17	0.00	NA	63.76	0.00	NA
	AD	31.02	83.22	< 0.01	48.73	67.95	< 0.01
	AP	30.53	0.77	< 0.05	48.05	3.07	< 0.10
	APC	20.3	16.02	< 0.05	41.64	28.98	< 0.10
France	Age	27.07	0.00	NA	49.14	0.00	NA
	AD	27.07	0.00	> 0.10	46.67	16.36	> 0.10
	AP	26.57	40.65	> 0.10	46.41	1.72	< 0.01
	APC	25.84	59.35	> 0.10	34.04	81.92	< 0.01

Ackowledgements The author is grateful to Maarten Bijlsma, Yana Vierboom, Pilar Zueras, Jeroen Spijker, Elisenda Rentería, Sergi Trías-Llimós and Elizabeth Wilkins for their suggestions, comments and patience. Any opinions that may appear in the present article represent only the author's point of view.

Funding European Doctoral School of Demography Fellowship, supported by Max Planck Institute for Demographic Research and Centre d'Estudis Demogràfics. And a FI Doctoral Scholarship, funded by the AGAUR (Agència de Gestió d'Ajuts Universitaris i de Recerca, Catalonia).

Availability of Data and Material The following article was made with data provided upon request by the Survey of European Health, Retirement and Ageing (SHARE), completely free-of-charge.

Code Availability The Code and Script used in the present article are available upon request in https://github.com/onbramajo/

References

Acosta, E., & van Raalte, A. (2019). APC curvature plots: Displaying nonlinear age-period-cohort patterns on Lexis plots. *Demographic Research, 41*(42), 1205–1234. https://doi.org/10.4054/DemRes.2019.41.42

Aichberger, M. C., Schouler-Ocak, M., Mundt, A., Busch, M. A., Nickels, E., Heimann, H. M., Ströhle, A., Reischies, F. M., Heinz, A., & Rapp, M. A. (2010). Depression in middle-aged and older first generation migrants in Europe: Results from the Survey of Health, Ageing and Retirement in Europe (SHARE). *European Psychiatry: The Journal of the Association of European Psychiatrists, 25*(8), 468–475. https://doi.org/10.1016/j.eurpsy.2009.11.009

Aziz, R., & Steffens, D. C. (2013). What are the causes of late-life depression? *The Psychiatric Clinics of North America, 36*(4), 497–516. https://doi.org/10.1016/j.psc.2013.08.001

Bell, A. (2014). A multiLife-course and cohort trajectories of mental health in the UK, 1991–2008 - A multilevel age–period–cohort analysis. *Social Science and Medicine, 120*, 21–30. https://doi.org/10.1016/j.socscimed.2014.09.008

Bergmann, M. Kneip, T., De Luca, G., Scherpenzeel, A. (2019). Survey participation in the Survey of Health, Ageing and Retirement in Europe (SHARE), Wave 1–7. Based on Release 7.0.0. SHARE Working Paper Series 41–2019. Munich: SHARE-ERIC.

Blazer, D. G. (2005). Depression and social support in late life: A clear but not obvious relationship. *Aging and Mental Health, 9*(6), 497–499. https://doi.org/10.1080/13607860500294266

Börsch-Supan, A. (2019). Survey of Health, Ageing and Retirement in Europe (SHARE) Waves 1 to 7. Release version: 7.0.0. SHARE-ERIC. Data set. https://doi.org/10.6103/SHARE.w7.700

Carstensen, B. (2007). Age-period-cohort models for the Lexis diagram. *Statistics in Medicine, 26*(15), 3018–3045. https://doi.org/10.1002/sim.2764

Carstensen B., Plummer, M., Laara, E., Hills, M. (2019). *Epi: A Package for Statistical Analysis in Epidemiology*. R package version 2.40, https://CRAN.R-project.org/package=Epi.

Chauvel, L., & Schröder, M. (2014). Generational inequalities and welfare regimes. *Social Forces, 92*(4), 1259–1283. https://doi.org/10.1093/sf/sot156

Chauvel, L., Leist, A. K., & Ponomarenko, V. (2016). Testing persistence of cohort effects in the epidemiology of suicide: An age-period-cohort hysteresis model. *PLoS ONE, 11*(7), e0158538. https://doi.org/10.1371/journal.pone.0158538

Clayton, D., & Schifflers, E. (1987). Models for temporal variation in cancer rates. II: Age–period–cohort models. *Statistics in Medicine, 6*, 469–481. https://doi.org/10.1002/sim.4780060406

Colman, I., & Ataullahjan, A. (2010). Life course perspectives on the epidemiology of depression. *Canadian Journal of Psychiatry, 55*(10), 622–632. https://doi.org/10.1177/070674371005501002

Cuadros, D.F., Tomita, A., Vandormael, A. et al. (2019) Spatial structure of depression in South Africa: A longitudinal panel survey of a nationally representative sample of households. Scientific Reports 9, 979 on the epidemiology of depression. https://doi.org/10.1038/s41598-018-37791-1

Dewey, M., Prince, M. (2005) Mental health. In A. Börsch-Supan, A. Brugiavini, H. Jürges, J. Mackenbach, J. Siegrist and G. Weber (eds), *Health, ageing and retirement in Europe—First results from*

the survey of health, ageing, and retirement in Europe, pp. 108–117. Mannheim Research Institute for the Economics of Aging (MEA)

Dobson, A., Hockey, R., Chan, H., & Mishra, G. (2020). Flexible age-period-cohort modelling illustrated using obesity prevalence data. *BMC Medical Research Methodology, 20*, 16. https://doi.org/10.1186/s12874-020-0904-8

Fernández-Niño, J.A, Bonilla-Tinoco, L.J, Manrique-Espinoza, B.S, Romero-Martínez, M., Sosa-Ortiz, A.L. (2018). Work status, retirement, and depression in older adults: An analysis of six countries based on the study on global ageing and adult health (SAGE), *SSM - Population Health* (6), 1–8 https://doi.org/10.1016/j.ssmph.2018.07.008

Ferrari, A.J, Charlson, F.J, Norman, R.E., Patten, S.B., Freedman, G., Murray, C.J.L., Whiteford, H.A (2013). Burden of depressive disorders by country, sex, age and year: Findings from the global burden of disease study 2010. *PLOS Medicine*, 10(11).

Fiske, A., Wetherell, J. L., & Gatz, M. (2009). Depression in older adults. *Annual Review of Clinical Psychology, 5*, 363–389. https://doi.org/10.1146/annurev.clinpsy.032408.153621

Fosse, E., & Winship, C. (2019). Analyzing age-period-cohort data: A review and critique. *Annual Review of Sociology, 45*(1), 467–492. https://doi.org/10.1146/annurev-soc-073018-022616

Frasquilho, D., Matos, M. G., Salonna, F., Guerreiro, D., Storti, C. C., Gaspar, T., & Caldas-de-Almeida, J. M. (2016). Mental health outcomes in times of economic recession: A systematic literature review. *BMC Public Health, 16*, 115. https://doi.org/10.1186/s12889-016-2720-y

Fryers, T., Melzer, D., & Jenkins, R. (2003). Social inequalities and the common mental disorders: A systematic review of the evidence. *Social Psychiatry and Psychiatric Epidemiology, 38*(5), 229–237. https://doi.org/10.1007/s00127-003-0627-2

Gennaro, C., Paccagnella, O., & Zaninotto, P. (2019). A model-driven approach to better identify older people at risk of depression. *Ageing and Society, 1–23*,. https://doi.org/10.1017/S0144686X19001077

Glenn, N. (2005). *Cohort analysis* (2nd ed.). Quantitative Applications in the Social Sciences. SAGE publications.

Guerra, M., Ferri, C., Llibre-Rodriguez, J., Prina, M., & Prince, M. (2015). Psychometric properties of EURO-D, a geriatric depression scale: A cross-cultural validation study. *BMC Psychiatry, 15*(12), 10. https://doi.org/10.1186/s12888-015-0390-4

Hansen, T., Slagsvold, B., & Veenstra, M. (2017). Educational inequalities in late-life depression across Europe: Results from the generations and gender survey. *European Journal of Ageing, 14*(4), 407–418. https://doi.org/10.1007/s10433-017-0421-8

Hobcraft, J., Menken, J., & Preston, S. (1982). Age, period, and cohort effects in demography: A review. *Population Index, 48*(1), 4–43. https://doi.org/10.2307/2736356

Holford, T. R. (1992). Analysing the temporal effects of age, period, and cohort. *Statistical Methods in Medical Research, 1*(3), 317–337. https://doi.org/10.1177/096228029200100306

Horackova, K., Kopecek, M., Machů, V., Kagstrom, A., Aarsland, D., Motlova, L., & Cermakova, P. (2019). Prevalence of late-life depression and gap in mental health service use across European regions. *European Psychiatry, 57*, 19–25. https://doi.org/10.1016/j.eurpsy.2018.12.002

Keyes, K. M., Nicholson, R., Kinley, J., Raposo, S., Stein, M. B., Goldner, E. M., & Sareen, J. (2014). Age, period, and cohort effects in psychological distress in the United States and Canada. *American Journal of Epidemiology, 179*(10), 1216–1227. https://doi.org/10.1093/aje/kwu029

Lavori, P. W., Klerman, G. L., Keller, M. B., et al. (1987). Age-period-cohort analysis of secular trends in onset of major depression: Findings in siblings of patients with major affective disorder. *Journal of Psychiatric Research, 21*(1), 23–35.

Marmot, M. (2005). Social determinants of health inequalities. *The Lancet No., 365*, 1099–1104.

Mattheys, K., Bambra, C., Warren, J., Kasim, A., & Akhter, N. (2016). Inequalities in mental health and well-being in a time of austerity: Baseline findings from the Stockton-on-Tees cohort study. *SSM Population Health, 2*, 350–359. https://doi.org/10.1016/j.ssmph.2016.04.006

Nielsen, B., Nielsen, J.P. (2014). Identification and forecasting in mortality models. *Scientific World Journal*, Article ID 347043.

Oksanen, T., Vahtera, J., Westerlund, H., Pentti, J., Sjösten, N., Virtanen, M., Kawachi, I., & Kivimäki, M. (2011). Is retirement beneficial for mental health?: Antidepressant use before and after retirement. *Epidemiology (Cambridge, Mass.), 22*(4), 553–559. https://doi.org/10.1097/EDE.0b013e31821c41bd

Pascual-Sáez, M., Cantarero-Prieto, D., & Blázquez-Fernández, C. (2019). Partner's depression and quality of life among older Europeans. *The European Journal of Health Economics, 20*, 1093–1101. https://doi.org/10.1007/s10198-019-01081-y

Prince, M., Reischies, F., Beekman, A. T. F., Fuhrer, R., Jonker, C., Kivelä, S.-L., Lawlor, B., Lobo, A., Magnússon, H., Fichter, I., van Oyen, H., Roelands, M., Skoog, I., Turrina, C., & Copeland, J. R. (1999). Development of the EURO-D scale—a European Union initiative to compare symptoms of depression in 14 European centres. *British Journal of Psychiatry, 174*, 330–338.

Riumallo-Herl, C., Basu, S., Stuckler, D., Courtin, E., & Avendano, M. (2014). Job loss, wealth, and depression during the Great Recession in the USA and Europe. *International Journal of Epidemiology, 43*(5), 1508–1517. https://doi.org/10.1093/ije/dyu048

Ryder, N. B. (1965). The cohort as a concept in the study of social change. *American Sociological Review, 30*(6), 843–861. https://doi.org/10.2307/2090964

Spiers, N., Bebbington, P., McManus, S., Brugha, T. S., Jenkins, R., & Meltzer, H. (2011). Age and birth cohort differences in the prevalence of common mental disorder in England: National Psychiatric Morbidity Surveys 1993–2007. *The British Journal of Psychiatry: The Journal of Mental Science, 198*(6), 479–484. https://doi.org/10.1192/bjp.bp.110.084269

Thomson, R. M., Niedzwiedz, C. L., & Katikireddi, S. V. (2018). Trends in gender and socioeconomic inequalities in mental health following the great recession and subsequent austerity policies: A repeat cross-sectional analysis of the health surveys for England. *BMJ Open 2018*(8), e022924. https://doi.org/10.1136/BMJopen-2018-022924

Van de Velde S., Bracke, P., Levecque K. (2010), Gender differences in depression in 23 European countries. Cross-national variation in the gender gap in depression, *Social Science and Medicine*, *71*(2), 305–313. https://doi.org/10.1016/j.socscimed.2010.03.035.

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer. ISBN 978-3-319-24277-4, https://ggplot2.tidyverse.org.

Wickramaratne, P. J., Weissman, M. M., Leaf, P. J., et al. (1989). Age, period and cohort effects on the risk of major depression: Results from five United States communities. *Journal of Clinical Epidemiology, 42*(4), 333–343.

World Health Organization. (2008). *Closing the gap in a generation: Health equity through action and the social determinants of health*. WHO.

Yang, Y., & Land, K. C. (2013). *Age-period-cohort analysis: New models, methods, and empirical applications*. CRC Press.

Zhao, K. X., Huang, C. Q., Xiao, Q., Gao, Y., Liu, Q. X., Wang, Z. R., & Xie, Y. Z. (2012). Age and risk for depression among the elderly: A meta-analysis of the published literature. *CNS Spectrums, 17*, 142–215.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Authors and Affiliations

Octavio Nicolas Bramajo[1]

[1] Centre d' Estudis Demogràfics (CED-CERCA), Bellaterra, Spain